

1. **Project Name:** Ultrasonic Processing of Materials
2. **Lead Organization:** University of Tennessee
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4. **Project Partners:** Dr. Qingyou Han-ORNL
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5. **Date Project Initiated and FY of Effort:** 10/1/2001, FY 03
6. **Expected Completion Date:** 9/29/04
7. **Project Technical Milestones and Schedule:** (Please provide the milestones/deliverables schedule for your project, both completed and planned.)

Table 1 lists the tasks, milestones, schedules, and the status of each task of the project. The past milestones have been completed and the future schedule and milestones have been planned.

Table 1. Technical milestones and schedule.

ID Number	Task/Milestone Description	Planned Completion	Actual Completion	Comments
Task 1	Experimental apparatus	3/31/02	3/31/02	Completed
Task 2	Degassing Al melts	9/30/03	9/30/03	Planned
Task 3	Thermodynamic modeling	3/31/03	3/31/03	Completed
Task 4	Solidification of alloys using ultrasonic energy	9/30/04		Planned
Task 5	Characterization of solidification microstructures	9/30/04		Planned
Task 6	Determination of fundamental mechanisms	8/31/04		Planned
Task 7	Industrial applications of results	9/30/04		Planned
Task 8	Reports and publications	9/30/04		Planned

8. **Past Project Milestones and Accomplishments:** (Provide a brief description of progress and accomplishments to date, with specific emphasis on progress towards milestones during the past calendar year.) Use current quarterly report.

The past primary milestones for the project are:

1. Year 1, Month 6 – Build apparatus for ultrasonic processing.

2. Year 1, Month 12 – Demonstrate grain refinement of aluminum alloys – Go/No Go criterion.
3. Year 2, Month 4 – Demonstrate production of globular microstructures for SSM applications.
4. Year 2, Month 8 – Demonstrate degassing of aluminum alloys using ultrasonic energy.

An ultrasonic processing apparatus has been built in before 3/31/02, the 6th month in the year 1 of the project (Past primary milestone No.1). During the last quarter, the problem with transducer overheating was addressed and the system is functioning properly. The length of the horn was decreased which allows the transducer to resonate with the same frequency at a high radiator temperature.

Task 2 (ultrasonic degassing) is close to completion. Samples of A356 aluminum were exposed to 20 KHz acoustic energy at one atmosphere for various processing times. Two reduced pressure testing specimens that were cast at 720°C are shown in Figure 1. Figure 1a shows the specimen without using ultrasonic vibration. A large amount of porosity can be observed on the polished surface of the specimen. Figure 1b shows the specimen that was treated with 300W ultrasonic vibration for only one minute. The porosity level was reduced substantially. Thus we have successfully demonstrated that degassing of aluminum alloys can be achieved using ultrasonic vibration (Past primary milestone No.4).

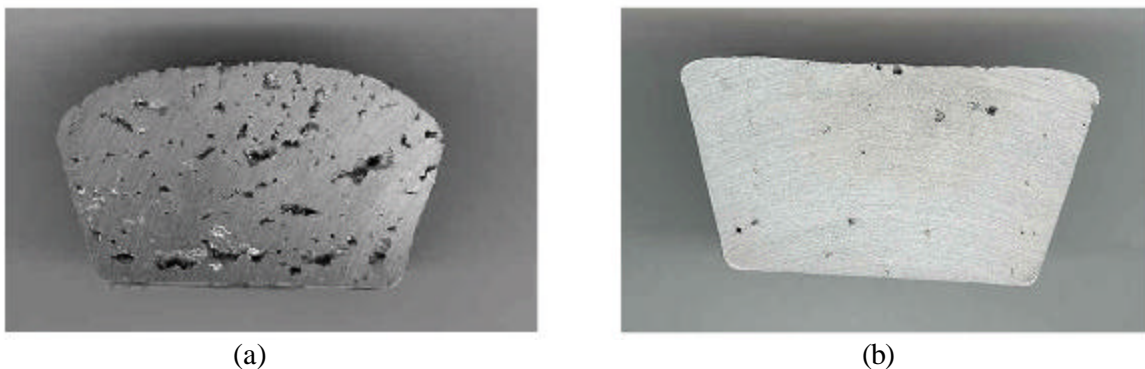


Figure 1. The effect of ultrasonic vibration on degassing in aluminum A356 alloy melt. (a) without ultrasonic vibration, and (b) with ultrasonic vibration.

Task 3 (thermodynamic modeling) has been completed. Thermodynamic simulations have been carried out to determine the solid fraction versus temperature curves for aluminum 3004 and A356 alloys, and 4340 steel. Figures 2 show the simulation results for aluminum 3003 and A356 alloys. These results have been used in Task 4 for processing of alloys at known solid fractions.

The past milestones No.2 and No.3 are associated with Task 4. The task is continuing with samples of A356 being fabricated by holding at various temperatures while injecting acoustic energy for a specific time. For example, some time-temperature settings were 10 seconds at 650°C, 645°C, 640°C down to 570°C. Twenty seconds at 650°C, 645°C, to 570°C; 40 seconds at 650°C, 645°C to 570°C. Figure 3(a) shows the microstructure of the specimen without ultrasonic vibration and Figure 3(b) shows the microstructure of ultrasonically processed A356 sample. As seen from the Figure 3(a), the grains are dendritic and the grain sizes are large without using ultrasonic vibration. With ultrasonic vibrations, the grain sizes are greatly reduced (past primary milestone No.2, Go/No Go criterion). More importantly spherical grains [Figure 3(b)] were obtained at certain ultrasonic processing

conditions. The grain sizes were much smaller than those without using ultrasonic energy. Thus we have successfully demonstrated the production of globular microstructure that is required for SSM applications (past primary milestone No.3). Further experiments have been planned to study the parameters such as duration/time for the application of ultrasonic energy, the intensity and frequency of the ultrasonic vibration, and the cooling rates of the samples.

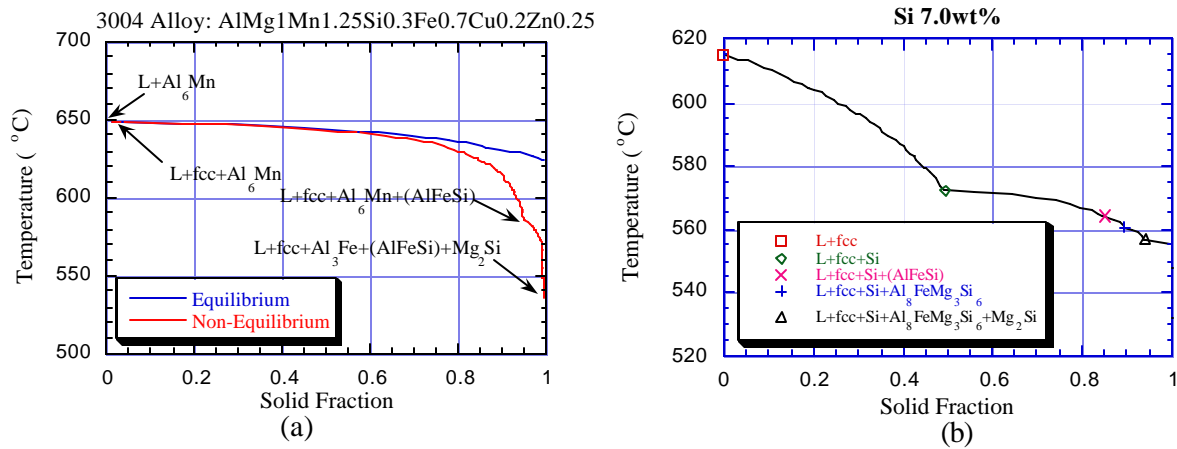


Figure 2. The solid fraction versus temperature curves for (a) aluminum 3004 alloy and (b) aluminum A356 alloy.

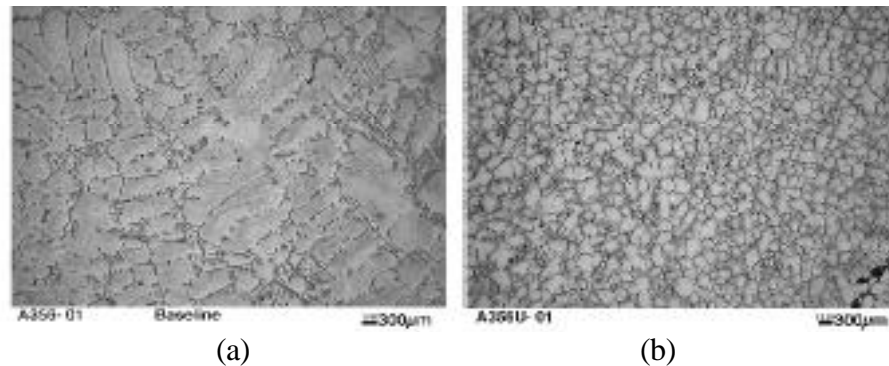


Figure 3. The microstructures of the aluminum A356 specimens (a) without using ultrasonic vibration and (b) with ultrasonic vibration during solidification. Under certain conditions, globular grains have been obtained in specimens processed using ultrasonic vibration.

9. **Planned Future Milestones:** (Outline your R&D plans and schedule for the remainder of the project, with specific emphasis on plans for the next calendar year.)

During the last year of this program, tasks 4-8 will be addressed. Task 4 is currently in progress – solidification of alloys using ultrasonic energy. Task 5 is also in progress – characterization of solidification microstructures. Task 6 will be continued also – the determination of fundamental mechanisms. Task 7 has been addressed in our program review with SECAT and will continue to be developed over the next year. Lastly task 8 – reports and publications will continue through next year.

10. **Issues/Barriers:** (Provide a brief description of any technical problems or barriers encountered and how these problems have been or will be resolved, or significant deviations from original scope and/or budget.)

None

11. **Intended Market and Commercialization Plans/Progress:** (Describe the end-use application and market potential for the research, and the plans and progress for commercial application/adoption, where appropriate; be sure to identify what the product of the research will be and how this product will be introduced/disseminated to the appropriate IOFs.)

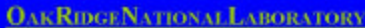

The aluminum and steel industries will use this technology to reduce grain sizes and to degas. On April 11, we had a project review with industrial partners at SECAT to discuss current status of this work. Discussed at this meeting was the application of this research to the aluminum industry. Also attending the meeting was Ohio Valley Aluminum, who was very interested in our initial research results. Ohio Valley Aluminum also sent us commercial aluminum 6062 alloys and grain refiners for comparison studies. Another meeting has been scheduled in August-September to review the research results and to discuss issues on how to implement the research results into industrial applications. Currently two papers will be submitted to a conference on lightweight materials. Also, one patent application is in progress.


12. **Patents, publications, presentations:** (Please list number and reference, if applicable.)

Patent application titled “Corrosion Resistant Coating for High Temperature Ultrasonic Processing” is in progress.

A paper entitled “on the Grain Refinement of A356 Aluminum Alloy Using Ultrasonic Vibrations” will be presented in the 2004 TMS annual meeting and will be published in the conference proceedings.

Highlight





Ultrasonic Processing of Materials

University Participants
Xiaogang Jian and Thomas T. Meek
University of Tennessee

National Laboratory Participants
Qingyou Han
Oak Ridge National Laboratory

Industry Participants
Carpenter Technologies Corporation
Secat, Inc.

Objective:

- To evaluate core principles and establish quantitative basis for the ultrasonic processing of materials, and demonstrate applications in key areas of solidification processing.

Project Tasks

1. Assemble experimental apparatus
2. Conduct solidification experiments of aluminum alloys and steel in an acoustic field
3. Conduct degassing experiments of aluminum alloy melts
4. Characterize solidification microstructures
5. Determine fundamental mechanisms during ultrasonic processing
6. Industrial Applications of Results
7. Reports and publications

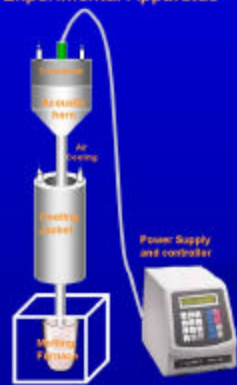
Benefits

- Enhance the understanding of the application of ultrasonic power to the processing of specialty steel and aluminum alloys.
- Material savings in the form of reduced grain refiner additions.
- Energy savings of one trillion Btu by 2025, and concomitant environmental benefits.

Key Aspects of This Work:

- Grain refinement of aluminum alloys during solidification
- Grain refinement during vacuum arc remelting of steel
- Degassing of alloy melts

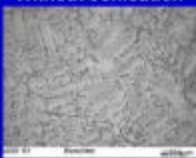
Experimental Apparatus



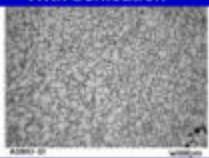
Initial Experimental Results:

- Globular microstructure has been obtained using ultrasonic energy. The size of the spherical grains is only about 300 μm , much smaller than those in specimens without using ultrasonic energy.

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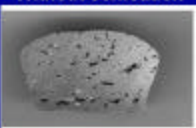


With sonication




- Ultrasonic energy has been successfully used for the degassing in aluminum melt.

Without sonication



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